A LOOK AT THE INTERIOR OF MARS. A. Khan[1], K. Mosegaard[2], P. Lognonne[1], M. Wieczorek[1], [1]*Departement de Geophysique Spatiale et Planetaire, UMR 7096, Institut de Physique du Globe de Paris, France (amir@gfy.ku.dk)*, [2]*Niels Bohr Institute, University of Copenhagen, Denmark.*

Introduction. The existence of a martian core has been widely accepted for some time now and even more so now given its ability to explain in a natural way the presence of the strong, spatially variable magnetic fields found by the MGS spacecraft. An ancient internal dynamo in analogy to the Earth is assumed to have been present which has magnetised the crustal material as it cooled through the Curie temperature [1, 2]. Other supporting evidence for a core comes from the SNC meteorites. These are found to be highly depleted in siderophile elements which, like on Earth, is attributed to their removel during core formation [3].

In having to unravel the origin and evolution of a planetary body such as Mars knowlegde of its internal structure is of paramount importance. The solar system bodies for which we presently can claim to have detailed insight into their interior properties are limited to the Earth and Moon. Even for the Moon the details are only perfunctorily known. Seismology has been the tool which has provided by far the most specific information on the interior of these two bodies. However, in the absence of such data for Mars, we have to revert to other geophysical tools in order to learn something about its interior.

The mean moment of inertia in combination with the mean martian density can give us an idea of the size of the core, as we do not know its composition nor that of the mantle. However, compositions of martian meteorites in combination with models of the planet's radial density distribution inferred from geophysical constraints [4, 5, 6], like mass and moment of inertia, lead to inferences about the composition of the martian mantle. From this the size of the core is generally believed to be around 1300-1500 km in radius [7]. A recent attempt at retrieving information on the state and size of the core using the second degree tidal Love number, suggested it to be fluid [8]. However, as noted in [8], the large observed value of k_2 can also be interpreted as the mantle being softer than the assumed elastic solid model because of the presence of partial melt at depth.

However, the above studies are essentially limited to forward modeling of some relatively simple models of the martian internal structure and therefore provide little information on what we can actually learn from the data. The present analysis is therefore concerned with a rigorous inversion of these geophysical data that provide information on the deep interior of Mars. The data used in the inversion are, mean moment of inertia (I), mean density ($\overline{\rho}$), second degree tidal Love number (k_2), tidal dissipation factor ($\overline{Q}$) and of course mean radius (R). Their values are, in the above order, 0.3649±0.0017, 3933±0.4 kg/m^3, 0.145±0.017, 92±11 and 3389.5 km [8, 9], respectively.

Method of Analysis. Our model of Mars is assumed spherically symmetric and divided into 7 shells of variable. The resolution adopted here was found on the grounds that the distribution of calculated data provided an adequate fit to the observed data distribution. Each of these shells is physically described by a number of parameters, which are, bulk and shear modulus, density, local dissipation factor and the radial extent of the layer (no correlation among the elastic parameters is assumed). By using this particular set of parameters the data become coupled in the inversion.

As regards the inversion, the framework needed to formalise the inverse problem involves the use of probability density functions (pdf's) to represent every single state of information in the problem [10, 11]. The outcome, given by the posterior pdf, is obtained by combining all available information. Samples from this posterior pdf are then obtained by employing a Markov Chain Monte Carlo method (MCMC) [*e.g.* 12]. Samples to be displayed, include the S-wave velocity (v_S), density (ρ) and dissipation (Q) as a function of radius. As in the study of [13], the posterior results will be analysed according to a Bayesian scheme.

Results. Samples from the posterior distribution are shown in figures 1 to 3, depicting S-wave velocity, density and dissipation as a function of radius. From these models information on the state and nature of the material making up the interior of Mars can be gleaned. From the S-wave velocity structure Mars seems to be crudely divided into a mantle, an outer and an inner core. A mantle extending to ∼1800 km depth seems to be indicated by the results, while the core makes up the rest, that is, comprises a radius of about 1500-1600 km. A subdivision of the core is further suggested, given the apparent lower velocities in what might tentatively be termed the outer core, when compared to the velocities in the mantle and inner core. The density models indicate a similar division with a mantle extending down to ∼1800 km depth and a core with a radius of ∼1500 km, in accordance with earlier speculations [e.g. 8]. Although the tidal dissipation seems to be less well constrained a somewhat similar division between mantle and core can be inferred, with lower Q-values pertinent for the region comprising the core. Concerning the dissipation it should be noted that the present model only considers dissipation due to purely inelastic effects within the body and does not take into account any dissipation occuring at a liquid/solid boundary.

The present state of the core contains clues to martian core evolution and is therefore very important. Possible scenarios of the evolution of the core involve three possibilities as summarised in [7]. These include an initially fully liquid, thermally convecting core sustaining a dynamo. As cooling of the core proceeds it is envisioned that at some point the heat flow out of the core will be due to conduction alone at which point the dynamo turns off. The core remains liquid throughout and requires the presence of a large amount of sulphur (as much as 10%) [14, 15]. A second model considers the possibility of complete core freezing [16]. The sulphur content of the core is low allowing the inner core to develop early and grow rapidly, while the outer core convects compositionally evolving toward the eutectic composition and the dynamo shuts down as the outer core becomes too thin to sustain it. However, arguments against the presence of a completely solidified core have been advanced by showing that for realistic models of mantle convection in Mars invoke a temperature of at least 1850 K at the core/mantle boundary, inhibiting solidification of the outer core [17]. The third scenario involves an inner core driving a dynamo while it is growing as the core cools. The dynamo shuts down as Mars evolves into the stagnant lid regime which results in the mantle heating up due to less efficient heat removal [17]. The consequences for present-day Mars is the presence of a non-convecting liquid outer core and a solid inner core.

Given our results here the third scenario of martian core evolution seems presently to be the most likely model. However, further analyses will confirm the robustness of these results.

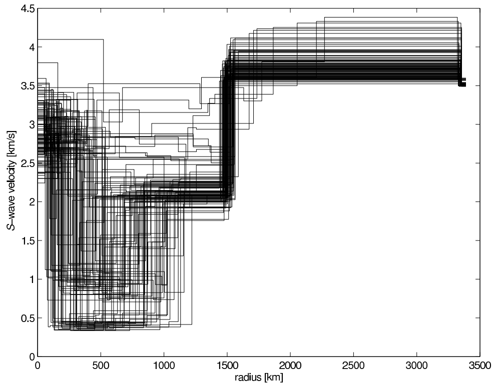

Figure 1: v_S samples from the posterior distribution.

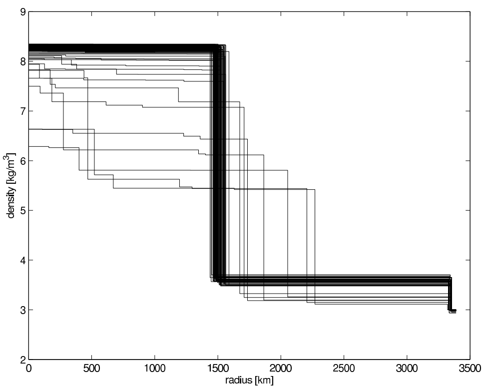

Figure 2: Density samples from the posterior distribution.

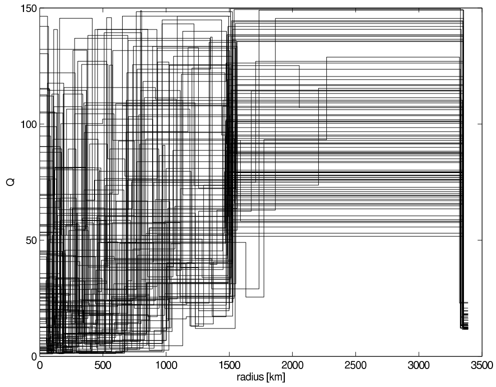

Figure 3: Samples from the posterior distribution showing tidal dissipation models.

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